THE EMISSIONS TRADING SCHEME: CHALLENGES AND FUTURE IMPACTS FOR GEOTHERMAL POWER PLANTS

Rebecca Lawson[1], Farrell Siega[1]

[1] Mighty River Power, PO Box 245, Rotorua 3040, New Zealand

Rebecca.Lawson@mightyriver.co.nz

Farrell.Siega@mightyriver.co.nz

Keywords: *emissions trading scheme, carbon dioxide, methane, default emissions factor, unique emissions factor*

ABSTRACT

The Emissions Trading Scheme (ETS) in New Zealand came into effect in 2008, and was subsequently extended to include geothermal power plants in 2010. For geothermal plants the gases applicable to the ETS are carbon dioxide and methane. Carbon dioxide and methane emissions vary considerably between different geothermal fields, with factors such as reservoir characteristics and plant operation affecting the true level of carbon emissions made by a plant. For several Mighty River Power operated plants, the Default Emission Factors (DEFs) originally published in legislations are considerably higher than the actual rates of emission by a plant.

This has led to Mighty River Power applying for lower Unique Emission Factors (UEFs) for plants where there is significant difference between DEF and UEF to manage the carbon emission fees payable to the ETS.

Mighty River Power has successfully complied with ETS legislative requirements since 2010 and currently holds UEFs for three of the five plants it operates.

The purpose of this paper is to examine the process of measuring and reporting carbon emissions in a geothermal power plant, the advantages and disadvantages of DEFs versus UEFs, and how recent changes to the ETS requirements impact the obligations geothermal power plants have under the legislation.

1. INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) occurred in 1992 and saw 196 parties, including New Zealand commit to “protect the climate system for the benefit of present and future generations of humankind”. One approach the UNFCC is using to achieve this goal is the Kyoto Protocol (United Nations, United Nations Framework Convention on Climate Change, 1992). The Kyoto Protocol was adopted in 1997, and commits participant countries to ensure that their “aggregate anthropogenic carbon dioxide equivalent emissions of greenhouse gases do not exceed their assigned amounts”. New Zealand is a participant in the Kyoto protocol and the first period that NZ was required to meet its obligations under the Kyoto Protocol began in 2002 (United Nations, 1998).

The New Zealand government developed the New Zealand Emissions trading scheme (NZ ETS) to help the country meet the requirements of the Kyoto protocol. The requirements for the NZ ETS were set out in the Climate Change Response Act passed in 2002, and came into effect in 2008.

The emissions trading scheme is applicable to stationary energy activities including those “using geothermal fluid for generating electricity or industrial heat, where the level of carbon dioxide-equivalent (CO2-e) emissions per annum exceeds 4000 tonnes”. This includes all of the geothermal power plants operated by Mighty River Power.

2. THE EMISSIONS TRADING SCHEME (ETS) – MEASURING AND REPORTING CARBON EMISSIONS IN A GEOTHERMAL POWER PLANT

At a minimum level, a geothermal power plant must track the steam flows produced to the station in order to complete an emissions return.

This in itself can pose some challenges as many power plants were built long before the Emissions Trading Scheme took effect. Many plants have steam flow meters on the main steam lines, but not in positions that would measure steam vented in the plant during upset conditions

2.1 Venting.

The Emissions Trading Scheme expressly excludes venting from well testing and bleeding as well as the disposal of spent geothermal fluid, but not steam vented from the station (Ministry for the Environment, 2009). Therefore the venting at the station needs to be accounted for appropriately.

MRP has developed a tool that examines process data to identify any time a station has vented steam. The tool examines variables such as separator pressure, plant output, vent valve positioning and steam flows to ascertain if venting may have occurred. If the variables indicate venting has occurred the steam flow is manually adjusted up for the entire period of venting. This is done in a conservative manner, with the vented steam flow value adjusted up to the steam flow measured immediately prior to venting. The thought process is that all steam that was previously being used for power production could be being vented. In reality it is unlikely that venting occurs at the full rate of steam production for the entire period of venting however there is no way to verify that a lower amount of steam was vented due to a lack of instrumentation on the venting lines. Adjusting the vented steam flow all the way up to the measured value prior to venting means that MRP slightly over-reports its steam flows for the ETS, but it ensures that all possible steam venting is adequately accounted for (Mighty River Power, 2011).

2.2 Steam Flow Monitoring

If a participant chooses to only measure the total steam flow through the station then they will have to base their emissions total on the Default Emission Factor (DEF).

The DEF is often substantially larger than the true rate of emission from a plant and as such doing the minimum to comply with the emissions trading scheme requirements means a participant will pay more for its annual surrender.

To apply for a Unique Emission Factor (UEF), a plant must also measure the gas levels in the steam flows. There is also an option to measure the gas levels in the condensate flow that is re-injected. Measuring the gas levels in the re-injected condensate allows a subtraction from the emissions calculated in the main steam flow based on the gas present in this condensate being re-injected.

In MRP’s experience a minimum of 8 samples over the span of the year has been required to ensure that there is sufficient data for the UEF application.

3. DEFAULT EMISSION FACTORS VS. UNIQUE EMISSION FACTORS.

All geothermal power plants in New Zealand will have a default emission factor (DEF) listed for them in the Climate Change (Stationary Energy and Industrial Processes) Regulations 2009.

This DEF is often substantially larger than the true rate of emission by a plant, and in some cases this creates a need to apply for a UEF to reduce the quantity of carbon emission the plant must pay for. In 2014 a request for data was sent out to all ETS Mandatory Participants to enable an update of the DEFs from those originally established in 2009. Mighty River Power submitted data on geothermal plants it operated where 3 or more years of historical data was available. This resulted in lowering of the emission factors for the Kawerau and Nga Awa Purua power plants.

Table 1 to the right shows both the original DEFs from 2009, the DEFs for 2015 onwards as well as the UEFs currently applicable to geothermal plants operating in New Zealand. The default emission factors in the table are taken from Schedule 2, Table 6 of the regulations, and measured emission factors are from the UEF approvals for the stations published in the New Zealand Gazette.

Despite the 2014 DEF review there are still a number of MRP operated plants that have actual rates of emission lower than the default factor. This is for two reasons:

1) For some plants (such as the Ngatamariki) there was insufficient historical data available to allow its DEF to be updated. Therefore Ngatamariki plant must continue to operate under the “Other” category of DEF until another DEF review occurs.
2) Geothermal reservoirs progressively degas with time during commercial production. Correspondingly, there is a reduction in the emission factor for the station. Figure 1to the right illustrates this degassing by showing the decrease in the UEF for the Nga Awa Purua (NAP) station over the past 5 years.

Plant	**Default Emissions Factor (tCO_2e/t steam) from CY2009 - 2014**	**Default Emissions Factor (tCO_2e/t steam) from CY2015**	**UEF for 2014 (tCO_2e/t steam)**
Kawerau II	0.0275	0.0194	0.0194
Kawerau Industrial	0.0275	0.0194	-
Kawerau KA24	0.0275	0.0194	-
Mokai I and II	0.0069	0.0052	-
Nga Awa Purua		0.0176	0.01336
Ngawha I and II	0.2120	0.0930	-
Ohaaki	0.0575	0.0591	0.0059
Poihipi Road	0.0049	0.0049	-
Rotokawa I	0.0214	0.0220	-
Wairakei station site	0.0050	0.0050	-
Any other plant or process using geothermal steam to produce electricity or industrial heat E.g. Ngatamariki Station	0.0300	0.0300	0.0160 (UEF for Ngatamariki station)

Table 1: Default Emission Factors

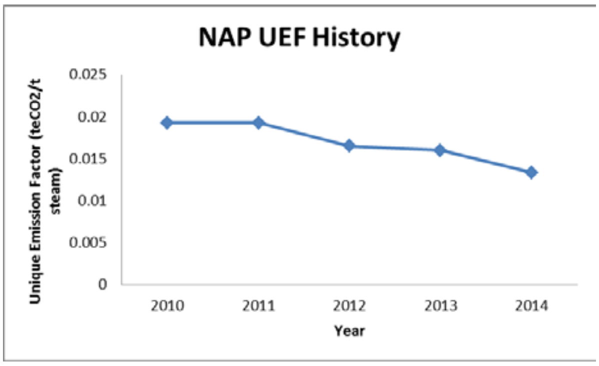

Figure 1: Nga Awa Purua station UEF trend

4. ADVANTAGES AND DISADVANTAGES OF UEFS AND DEFS

4.1 UEF

The main advantage of UEF is clearly the ability to pay for a lower amount of carbon emissions per tonne of steam produced for a given plant. However the UEF has several disadvantages, largely due to its data requirements.

Once a UEF has been approved if the participant wishes to continue using the UEF for the next calendar year they must undertake sufficient monitoring to be able to prove their emission factor has not changed by more than +/- 5% over that year. On the surface this does not seem difficult; however it is often challenging to maintain less than a 5% change in the emission factor due to the degassing of fields as a result of production. In addition to this, the data must meet a 90% confidence interval calculation and if it does not the percentage change calculated could be deemed invalid and reversion to the DEF would be required.

4.2 DEF

The main disadvantage of the DEF is that for many plants it will require a much higher carbon obligation for the year. However staying with a DEF has several advantages over a UEF

No gas measurement is required to use the DEF, and thus there are no costs for these activities or requirements for confidence intervals or percentage change allowances.

The internal personnel time to conduct a UEF review is considerable. By staying with a DEF staff time is available for other projects/technical work.

5. RECENT CHANGES TO ETS LEGISLATION

5.1 ERUs, CERs, RMUs vs. NZUs

5.1.1 What are ERUs, CERs and RMUs?

In the initial period of the NZ ETS the Kyoto protocol issued carbon credits called CERs, ERUs and RMUs to incentivize projects on an international level that reduced carbon emissions. Several different types of credits were available depending on the nature of the project. What each of these units were issued for is described below:

- ERUs = Emission Reduction Units. ERUs are generated by Joint Implementation (JI) projects. These are projects that where a country or company within that country will drive an emission reduction project in another country to earn ERUs . The main difference of a JI project (compared to a Clean Development Mechanism project described below) is that JI projects can only be hosted in countries that have an emission reduction or limitation commitment under the Kyoto protocol.
- CERs = Certified Emission Reduction Units. CERs are generated by Clean Development Mechanism (CDM) projects offshore. This is where developed countries or companies within those countries invest in projects that reduce green-house gas emissions or sequester carbon in forests in developing countries (Ministry for the Environment, 2014). The key idea is that the CDM will stimulate development and emission reductions in developing countries while helping industrialised countries flexibility in meeting their emission targets.
- RMUs = Removal Units. RMUs are Kyoto protocol units generated through storing carbon in trees.

5.1.2 Legislation Change: Why do CERs, RMUs and ERUs matter?

Prior to the 2015 calendar year, participants in the New Zealand ETS were able to surrender Kyoto Protocol issued, international carbon credits such as ERUS, CERs and RMUs to pay for their obligations in New Zealand.

However in May 2014 an amendment was made to the ETS which negated the option of using international carbon credits. As of 2015 all carbon credits surrendered under the New Zealand ETS must now be New Zealand generated credits (Bridges, 2013) . These include NZUs and NZ AAUs.

- NZUs are either those given to foresters in the ETS or those given to Industrial Allocation Recipients.
- NZ AAUs are credits that have been granted to companies in New Zealand that have participated in Projects to Reduce Emissions (PRE) or the Permanent Forest Sink Initiative (PSFI).

Geothermal power projects completed in the 2008-2012 period will have been assigned NZ AAUs as part of the PRE program due to the much lower carbon emission rates of geothermal compared to tradition thermal plants such as coal and gas.

5.2 Impact of the Amendment

The impact of this amendment is substantial given that ERUs and other overseas carbon credits have been the major proportion of credits surrendered in the New Zealand ETS over the last three years. Figure 2 below shows the proportion of each type of credit surrendered in the 2013 calendar year.

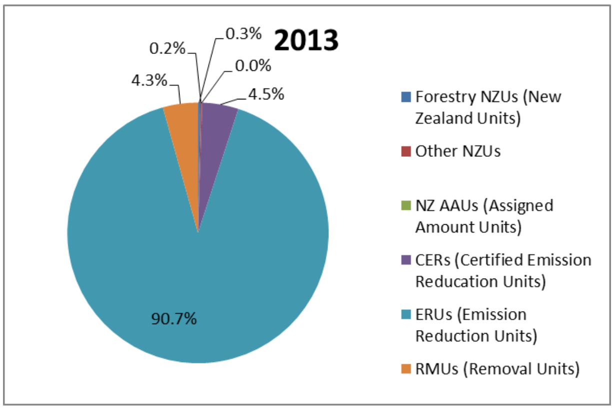

Figure 2: 2013 NZ ETS Carbon Credit Surrender Proportions

The inability to use CERs, ERUs and RMUs in the NZ ETS from 2015 both reduces demand on the international market for those units, as well as greatly increases demand for NZU's in the New Zealand Market. With supply of NZUs remaining approximately the same, the increase in demand has resulted in a large increase in prices for NZUs compared to pre – 2015 prices.

For example on the 1st December 2014 ERUs could be purchased for NZD$0.15 whilst NZUs averaged NZD $4.60 in the New Zealand Carbon Market. On 3/08/15 (3 months after the change to NZ ETS legislation) the NZU spot price had increased from 2014 to sit at $6.95 (Carbon Forest Services Limited, 2013)

Comparing prices paid to the ETS in 2014 which allowed ERUs to be surrendered at a price of $0.15 per credit, the need to pay the 2015 obligation in NZUs currently priced at $6.95 on the NZU spot market represents approximately a 46 fold increase in the cost of carbon credits to the participant and greatly increases the driver for participants to undertake UEF reviews.

6. UEF REVIEW PROCESS - CHALLENGES

With an increased driver for geothermal power plants across the board to undergo UEF reviews, there is a level of knowledge that can be shared for those who have never completed the process.

On the surface the process seems simple, with the main part of the review being provision of the gas measurement results and the UEF calculation. However there are several other factors that should be taken into consideration to help the process go smoothly.

6.1 Calibration Certificates

For any steam flow used in the UEF calculation, a relevant calibration certificate must be provided for the meter. Certificates for the entire year must be made available to the reviewer. Plants will have a standard Preventive Maintenance (PM) schedule for calibration of all the instrumentation on site so the certificates are often readily available; it's the compiling of certificates for several different sites that can be the time consuming factor.

6.2 Variation in gas results

Geothermal power plants are inherently unique compared to other participants in the ETS as there is no control over the gas levels flowing in the steam to the station. What is produced from the well is essentially what is emitted.

This can create some challenges with variation in gas measurements as the plant makes operational changes. For example when a plant shut down occurs (even if wells are left on bleed for the duration of the shut-down) the gas levels in the main steam flow will be elevated for a period of time afterwards. Additionally if a new well becomes operational in the steam field it will cause an elevation in the total gas levels at the station.

The basis of the UEF review is to not only check the calculation method, but also check the statistical validity of the UEF. Variation in the gas results due to steam field operational requirements requires explanation to the reviewer (MRP has needed to provide explanation for spikes in results corresponding to plant shut downs or new wells to the UEF reviewer in the past), as well as careful monitoring to ensure that they do not jeopardize the UEF meeting the statistical requirements of the review. Often these elevated results are statistically 'evened out' by the other measurements in the year to meet the confidence interval requirements, however if a plant experiences several large operational changes in a year there is the potential for these higher results to skew the statistics of the UEF calculation.

Another issue experienced by MRP is variation in gas results from a specific type of condensate line configuration. This type of condensate line exists in some OEC units where condensate is be mixed back in with the brine to both dilute and lower the pH of the brine. In these instances there is usually a very short pipe run of pure steam condensate before it is mixed with the main brine flow. This configuration means that condensate is sampled shortly after it has condensed and the fluid has not yet reached an equilibrium state with the non-condensable gases that were present in the steam. As a result the non-condensable gases (including CO_2 and CH_4) form bubbles in the main fluid flow. These bubbles appear to be unevenly distributed in the fluid flow and this can cause samples taken minutes apart to vary markedly simply because one sample takes in a gas bubble, whilst another does not. In some cases, the variation between samples has been significant enough that MRP has chosen to exclude the condensate measurement and thus the benefit of having a condensate subtraction in a UEF review. This means that the final UEF will be slightly higher, but negative statistical impact of the condensate data is removed, thus improving the overall statistics of the UEF.

6.3 Global Warming Potential

6.3.1 What is Global Warming Potential?

The UEF calculation takes into account the global warming potential (GWP) of different types of carbon based gases. The global warming potential accounts for how much heat a greenhouse gas traps in the atmosphere relative to carbon dioxide. This is related to how fast a gas will breakdown in the atmosphere relative to CO_2. Therefore the GWP is very dependent on both the lifetimes of a gas in the atmosphere and the time horizon used to calculate the GWP

As GWP is assessed relative to CO_2, no adjustment in the UEF calculation is required for the CO_2 measurements taken. However for methane (CH_4) the GWP is currently set at 25 for the purposes of the ETS. This was amended from a value of 21 which was applicable prior to calendar year (CY) 2014.

This means that for every unit of methane measured in the steam flow, the value must be multiplied by 25 for the purposes of the UEF calculation.

The GWP application in the UEF is an interesting addition due to the value depending on the time horizon used to calculate it. For the purposes of the ETS a time horizon of 100 years has been applied (UNFCC, 2014).

6.3.2 How might GWPs change in future?

For methane, the difference in calculated GWP for a time horizon of 20 years versus 100 years is almost a factor of 3 lower. The reason this value is so different is because methane has a lifetime in the atmosphere of approximately 12.6 years. Therefore whilst initially CH_4 has a large heat trapping effect, as it is removed from the atmosphere this effect is reduced to the point where over a 100 year average the effect is greatly reduced compared to a 20 year average effect.

GWPs have varying levels of uncertainties depending on the time horizon. As such the estimated uncertainty for the GWP of CH_4 is +/- 15% in the current version of the ETS. Additionally because the method for calculating GWP is dependent on the atmospheric CO_2 concentration, the GWP values are likely to increase with time due to increasing levels of CO_2 in the atmosphere as a background gas (Manning, Reisinger, & Bodeker, 2009).

It can be seen that simply from calculation uncertainty, changes in time horizons and background changes in CO_2 levels in the atmosphere there is significant potential for GWP values to change.

A challenge related to the use of GWPs in the ETS in future is whether they will see repeated rounds of increase as part of reviews, whether they will become fixed or whether an alternative method for evaluating relative effects of each gas is adopted.

6.4 Differences in UEF between plants operating on the same field

On the Rotokawa geothermal field, there are two plants. One being the original Rotokawa plant commissioned in 1997, and the other being the Nga Awa Purua station commissioned in 2010.

Despite operating on the same geothermal field, differences in the generation equipment means that there plants have very different measured emission levels per tonne of steam produced. This difference stems largely from Nga Awa Purua being a triple flash plant, whilst Rotokawa plant is only a single flash plant.

This is because the majority of gas present in the two phase fluid will move off into the steam in the first stage of steam separation. Subsequent stages of steam separation will still contain gas, but these levels will be very low compared to those in the steam flow from the first stage of separation. This is important as the UEF calculation relies heavily on the amount of gas per unit of steam flow.

Nga Awa Purua (NAP) flashes steam at pressures of approximately 23 bar(g), 8 bar(g) and 1.6 bar(g), whilst Rotokawa flashes the steam at a single pressure of 25 bar(g). For a triple flash plant, a tonne of HP steam has the same effect on the UEF calculation as a tonne of LP steam. Therefore for each tonne of produced fluid at Nga Awa Purua, there is a greater tonnage of steam flow (based on the additive HP, IP and LP steam flows) applicable for the UEF calculation. The t amount of gas per unit of two phase steam that is produced to the two stations is essentially the same, but the amount of steam flow it is spread over is much greater for NAP. The net result is a reduced emission factor 'per tonne of steam' for the Nga Awa Purua station compared to that seen at Rotokawa station. Equation 1 below shows the basic format of the calculation for a plant with two stages of separation where Pressure of Steam Flow 1 > Pressure of Steam Flow 2 and each steam flow is multiplied by its respective gas content.

$$\mathbf{E = ((Steam\ Flow_1 \times Gas\ Level_1) + (Steam\ Flow_2 \times Gas\ Level_2))/(Steam\ Flow_1 + Steam\ Flow_2)}$$

Equation 1: Basic Emission Factor Calculation

This is important as it clearly shows that two plants operating on the same field may not necessarily have the same emission factor and that data collected from a plant already on a geothermal field is not necessarily applicable to any new plants built on that same geothermal field.

6.5 Future Amendments to Legislation

Despite the operation of the NZ ETS, New Zealand has not been meeting its obligations under the Kyoto protocol. Given that the NZ ETS was designed to help NZ meet these obligations, further amendments to the ETS are likely.

A key piece of the legislation currently applicable to geothermal power plants is that they are only required to pay for 50% of their total emissions to the ETS.

This was originally a transitionary measure that was only meant to be applicable until 2012, however this has been 'extended indefinitely' as of 2012 set of amendments.

It is hypothesized that in future revisions of the ETS that this extension of the transitionary measure could be removed.

5. SUMMARY

Prior to CY15 the NZ ETS has been a minor component in the operation of a geothermal power plant, however with the recent exclusion of international carbon credits from the NZ ETS the cost of complying with the ETS will have an increased focus moving forward.

There are both advantages and disadvantages around the DEFs and UEFs and what is most suitable for any given plant is largely dependent on whether measurements can meet the statistical requirements of a UEF.

The UEF process in itself holds several challenges for those who have never completed the process before. Concepts such as GWP, plant operational impacts and differences between plants on the same field are some of the factors that will be encountered through this process.

The ETS itself also proves a challenge with ongoing changes to legislation likely as New Zealand strives to meet its commitments under the Kyoto Protocol.

BIBLIOGRAPHY

, Environmental Protection Authority. (2013, July 1). *2013 Emissions Trading Scheme Report.*

Blanchard, R. H. (2009). *Climate change (Stationary Energy and Industrial Processes) Regulations 2009.* Wellington: Order in Council.

Bridges, S. (2013, December 06). *Decisions on Kyoto Protocol emission units*. Retrieved August 06, 2015, from The official website of the New Zealand Government: http://www.beehive.govt.nz/release/decisions-kyoto-protocol-emission-units

Carbon Forest Services Limited. (2013). *New Zealand Unit (NZU) & Emission Reducation Unit (ERU) Chart*. Retrieved August 06, 2015, from Carbon Forest Services: http://www.carbonforestservices.co.nz/nzueru-chart.html

Environmental Protection Authority. (2008). *About the NZEUR*. Retrieved August 06, 2015, from New Zealand Emission Unit Register: http://www.eur.govt.nz/about-us

Manning, M., Reisinger, A., & Bodeker, G. (2009). *Global Warming Potentials and Alternate Metrics.* Wellington: New Zealand Climate Change Research Centre.

Mighty River Power. (2011). Emissions Trading Scheme Data Review.

Ministry for the Environment. (2009). *Guide to Reporting for Geothermal Fluid Activities under the New Zealand Emissions Trading Scheme.* Wellington.

Ministry for the Environment. (2014, 07 01). *Clean Development Mechanism*. Retrieved 08 12, 2015, from http://www.mfe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/clean-development-mechanism

UNFCC. (2014). *Global Warming Potentials*. Retrieved August 2015, from United Nations Framework Convention on Climate Change: http://unfccc.int/ghg_data/items/3825.php

United Nations. (1992). *United Nations Framework Convention on Climate Change.* Retrieved August 07, 2015, from United Nations Framework Convention on Climate Change: http://unfccc.int/essential_background/items/6031.php

United Nations. (1998). *Kyoto Protocol to the United Nations Framework Convention on Climate Change.* Retrieved August 07, 2015, from United Nations Framework Convention on Climate Change: http://unfccc.int/essential_background/kyoto_protocol/items/6034.php